Chapter 6
Renaissance Engineers

Medieval and Renaissance Europe possessed only one effective heat engine, the combustion engine in the form of the cannon (Figure 6.1) [1].

The credit for making pressure exerted by the atmosphere entirely explicit belongs to Otto von Guericke (reprint 1963), who in 1672 published the famous book in which he described his air pump and the experiments that he made with it from the mid 1650s onwards. His famous demonstration is illustrated in Figure 6.2. Once it was understood that atmosphere exerts pressure, it was a matter of creating a vacuum and allowing the atmospheric pressure to move the piston in a cylinder.

Denis Papin (1647–1712) a French physicist, mathematician and inventor is best known for his pioneering invention of the steam digester, the forerunner of the steam engine [5]. He visited London in 1675, and worked with Robert Boyle from 1676 to 1679, publishing an account of his work in *Continuation of New Experiments* in 1680. During this period, Papin invented the *steam digester,* a type of pressure cooker. He first addressed the Royal Society in 1679 on the subject of his digester, and remained mostly in London until about 1687, when he left to take up an academic post in Germany. While in Leipzig in 1690, having observed the mechanical power of atmospheric pressure on his "digester", he built a model of a piston steam engine, the first of its kind, see Figure 6.3. The Papin experiment was a metal tube (closed at one end) with a piston inside. Under the piston there was a small quantity of water which, heated and transformed into steam, raised the piston which reached the edge of the cylinder where it was stopped by a flange. A stream of cold water was sprayed onto the cylinder. The steam inside condensed. This produced a partial vacuum and the outside air pressure forced the piston down (active stroke). The tube had three roles: boiler, cylinder and steam condenser. The steam engine will build pressure step by step, separating those three roles [3].

Thomas Savery (1650–1715) was an English military engineer and inventor who in 1698 patented the first crude steam engine, based on Denis Papin's Digester or pressure cooker of 1679. On 2 July 1698 Savery patented an early steam engine; he demonstrated it to the Royal Society on 14 June 1699. In 1702 Savery described the machine in his book *The Miner's Friend; or, An Engine to Raise Water by Fire*, in which he claimed that it could pump water out of mines. His machine (see Fig-

Fig. 6.1 A 17th century forge-welded iron cannon in Thanjavur (S. India). (Courtesy Wikipedia)

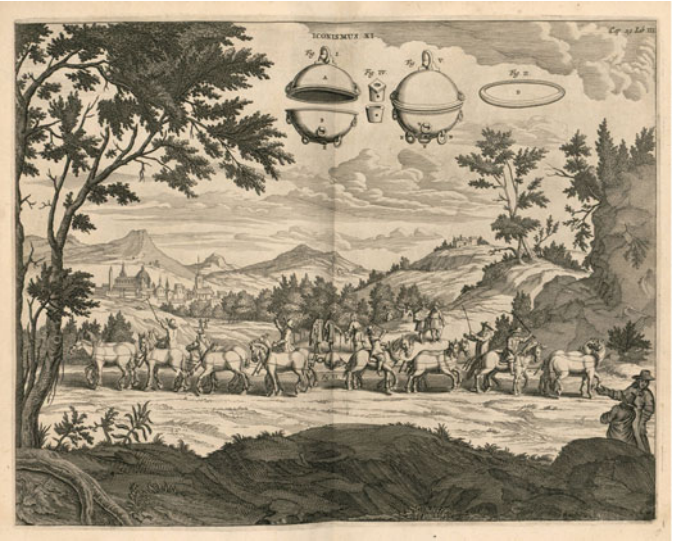

Fig. 6.2 Teams of horses trying unsuccessfully to pull apart vacuum-filled copper spheres in Magdeburg demonstration for Emperor Ferdinand III. (Courtesy Gaspar Schott of Wikipedia)

ure 6.4), consisted of a closed vessel filled with water into which steam under pressure was introduced. This forced the water upwards and out of the mine shaft. Then a cold water sprinkler was used to condense the steam. This created a vacuum which sucked more water out of the mine shaft through a bottom valve [7].

In 1705 Papin, with the help of Gottfried Leibniz, developed a second steam engine using steam pressure rather than atmospheric pressure. Papin's steam engine was the first breakthrough since Hero's reaction turbine of the 2nd century BC, which never functioned in reality. In the installation at Kassel (Figure 6.5), steam was fed from boiler "o" to a vessel "b" in which there was a float serving as a piston

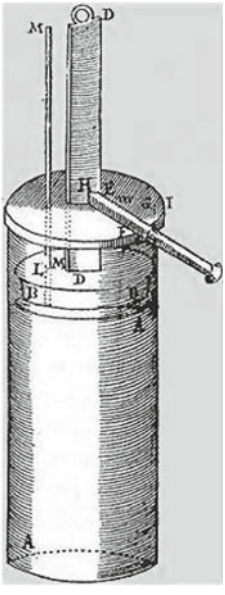

Fig. 6.3 The first steam engine 1690. (Courtesy Wikipedia)

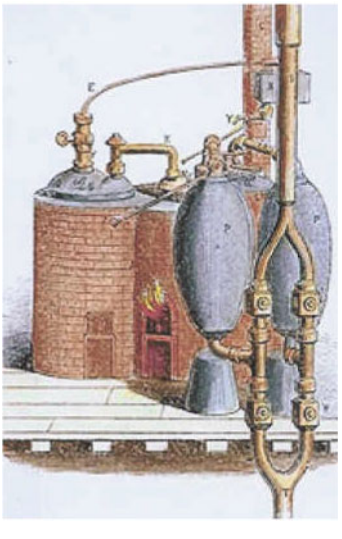

Fig. 6.4 Thomas Savery (1698) vacuum pump. (Courtesy Wavesmikey at Wikipedia)

"c". Papin planned to fill a container "d" in the piston with red-hot scrap iron in order to superheat the steam, but in reality this could not be done. When the steam pushed the piston downwards, the check valve "e" of the container for water to be pumped was closed. Simultaneously the check valve "f" of the ascending pipe "g" was opened and the water was pumped into a cistern "h", from where it flowed to the

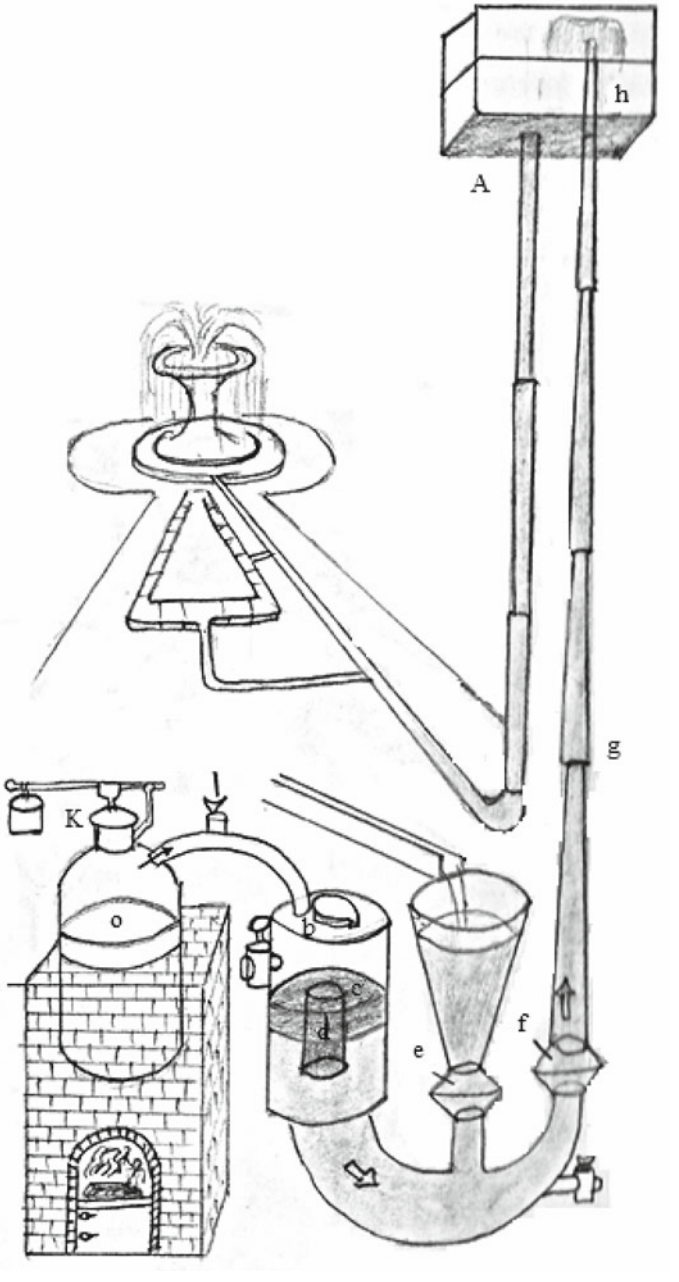

Fig. 6.5 Papin Steam Engine installed in Kassel gardens of the Duke of Hesse. (Artist impression by Lakshmi)

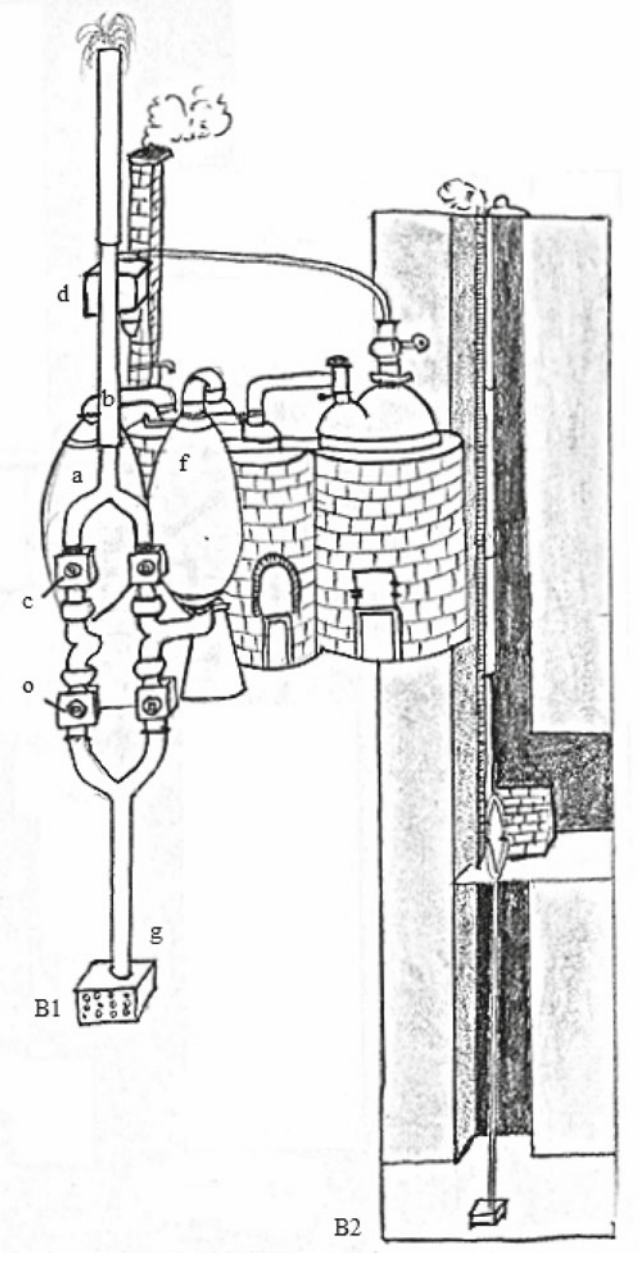

Fig. 6.6 Thomas Savery Steam Engine in action in a water-logged mine (Artist impression by Lakshmi)

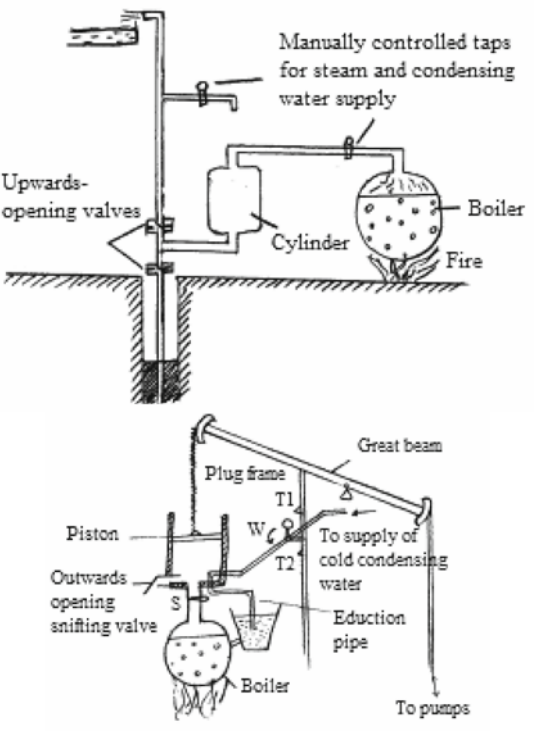

Fig. 6.7 Improvements in Newcomen Engine 1712 compared with Savery Engine (above). (Artist impression by Lakshmi)

fountains. When the piston reached the bottom of "b" a tap "j" on "c" was opened and the steam escaped. Because of the water pressure, "f" was then closed and "e" opened and more water poured in. "k" is a safety valve [5].

Savery's Vacuum pump installed in a water logged mine is illustrated in Figure 6.6. It had neither a piston nor a safety valve. Steam from the boiler was fed into a vessel "a" and the water in it was forced out through an ascending pipe "b" by way of check valve "c". When "a" had been emptied, the flow of steam was stopped and the vessel was cooled by means of cold water, which was sprayed over it from vessel "d". Since a vacuum was created when the steam was condensed, water was again sucked into "a" by way of a check valve "e". While "a" was being cooled, steam was fed into the water filled vessel "f", which was emptied, cooled and refilled with water "g".

Further developments, up until the appearance of James Watt are recently being questioned, e.g., Valenti [8] writes

> The early history of the invention of the steam engine shows without doubt that the British Royal Society, including Isaac Newton personally, deliberately prevented the industrial and naval applications of steam power for nearly 100 years. In fact, the Royal Society was so intent on burying Denis Papin's 1690 invention of a paddle-wheel-driven steamship, worked

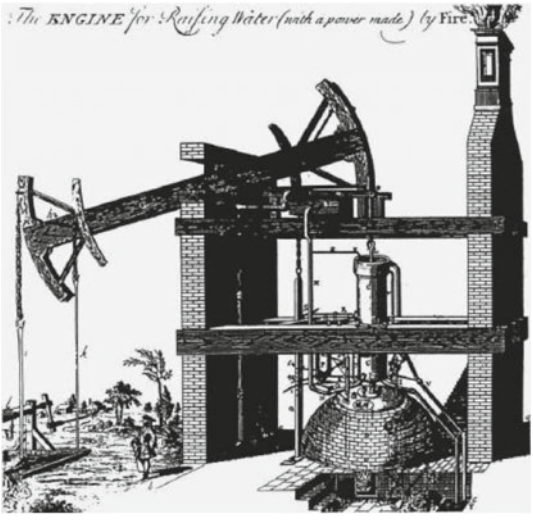

Fig. 6.8 Newcomen Engine Installation, (Courtsey Dartmouth Directory Ltd)

out in collaboration with Gottfried Wilhelm Leibniz, that it stole his work, and created a mythical story of how two British "Newtonian" heroes, Savery and Newcomen, invented the steam engine, for the sole purpose of raising water from coal mines – a myth that has persisted in the history books until today.

Be that as it may, we will proceed to discuss further developments in steam engines prior to the industrial revolution.

Thomas Newcomen (1663–1729) made explicit provision for the expulsion of air from the cylinder. The snifting valve in Figure 6.7 opened outwards in such a way that the rush of steam into the cylinder at the beginning of each cycle carried the accumulated air out with it through the valve. In this way once a cycle, the engine made a wheezing noise – like a man snifting with a cold – as it cleared itself of the air. The movement up and down of the plug frame, a long board hanging from the great beam, causes the tappet, or plug "T_1" set in it to trip the weight-operated valve, "W". When the plug frame moves in the opposite direction, another tappet, "T_2" resets the valve. A similar mechanism (not shown) controls the steam supply by means of the valve "S". The eduction pipe enables the condensed steam and the warmed condensing water to be returned via a well to the boiler, thus conserving heat (see also [4]).

Newcomen's steam engine was the first practical device to harness the power of steam to produce mechanical work. His first working engine was installed at a coal mine at Dudley Castle in Staffordshire in 1712. Such engines were used throughout England and Europe to pump water out of mines starting in the early 18th century, see Figure 6.8 and were the basis for James Watt's later improved versions [2]. Although Watt is far more famous today (largely due to Matthew Boulton's tireless salesmanship), Newcomen rightly deserves the majority of the credit for widespread introduction of steam power.

References

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